Vented Airbags
a new promising technology for Mars landers

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SUMMARY

- ✓ Initial ExoMars Requirements in 2006
- ✓ Vented vs Non Vented Airbag
- ✓ New Vented Airbag Design for a 600kg Lander in 2008
- ✓ New Vent Control Logic
- ✓ Vent Test in Vacuum Chamber
- ✓ Inflation Test in Vacuum Chamber
- ✓ Material testing and compatibility with DHMR process
- ✓ Conclusions

26/3/2009 11:38

Initial ExoMars Requirements in 2006

Lander mass:	480 kg
Vertical velocity at impact:	12 m/s
Horizontal velocity at impact:	9 m/s
Lander attitude at impact:	± 12 deg
Terrain slope:	± 18 deg
Rock clearance:	0.5 m
Max deceleration at impact:	40 g_E

Vented Airbag

FUNCTIONAL SEQUENCE

- Airbag inflation and restraint release
- Cushioning transfers kinetic energy to the inflation gas
- Gas is vented to the atmosphere (careful control of vent timing to avoid turnover)
- Final short freefall to the ground

DESIGN

- Torus with hexagon plan form
- Elliptic section
- Segment volume of 2 m^3 (12 m^3 total)
- Segments divided by internal bulkheads and connected by small cross vent orifices
- Each segment vents independently through a vent valve
- Vent Control Unit based on laser sensors
- Petal type valve

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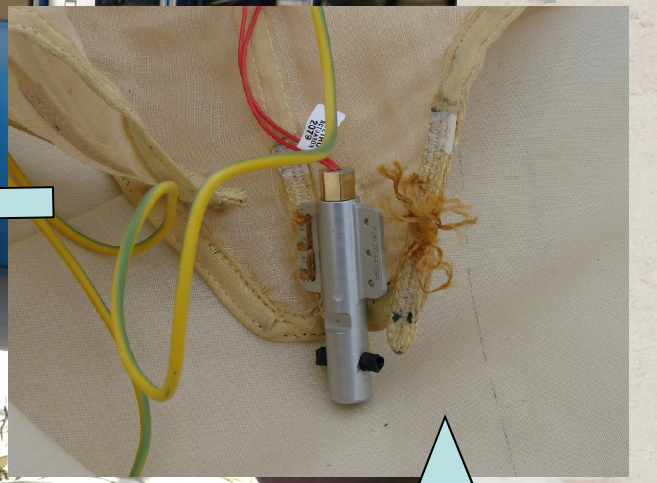
Vented Airbag



Vented Airbag

Vented Airbag

Non Vented Airbag

FUNCTIONAL SEQUENCE

1. Airbag inflation and restraint release
2. Cushioning transfers kinetic energy to the inflation gas
3. Several rebounds reduce kinetic energy to zero
4. ABS retraction
5. LP petals opening and rover egress

DESIGN

- Set of four billiard ball rack airbags (geometrically the same)
- Each airbag is a six lobes with 2m diameter
- Airbag petal volume 16.2 m^3 => total volume 64.8 m^3

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Non Vented Airbag

Vented vs Non Vented

Ver ag

Adva
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Lowe

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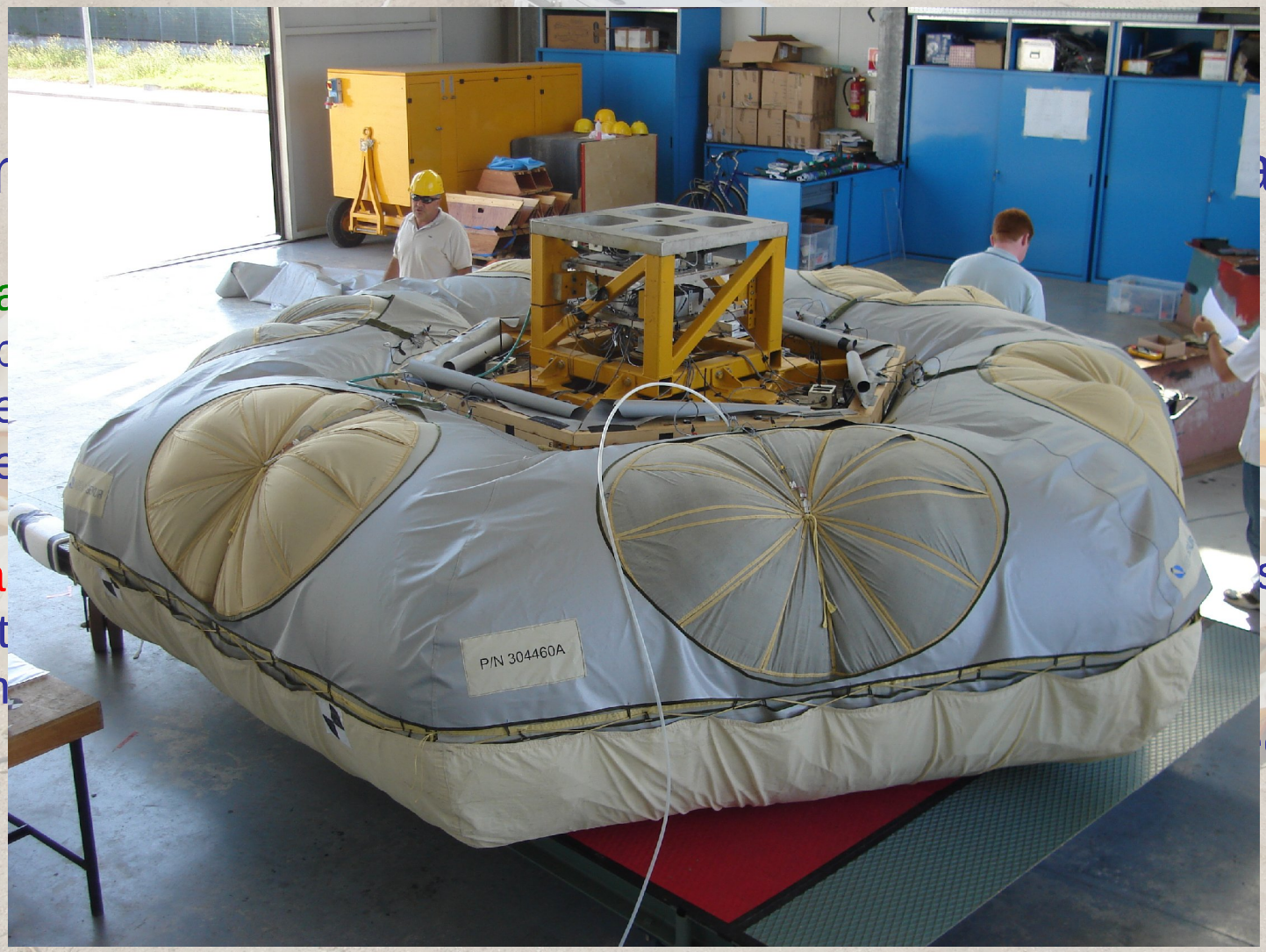

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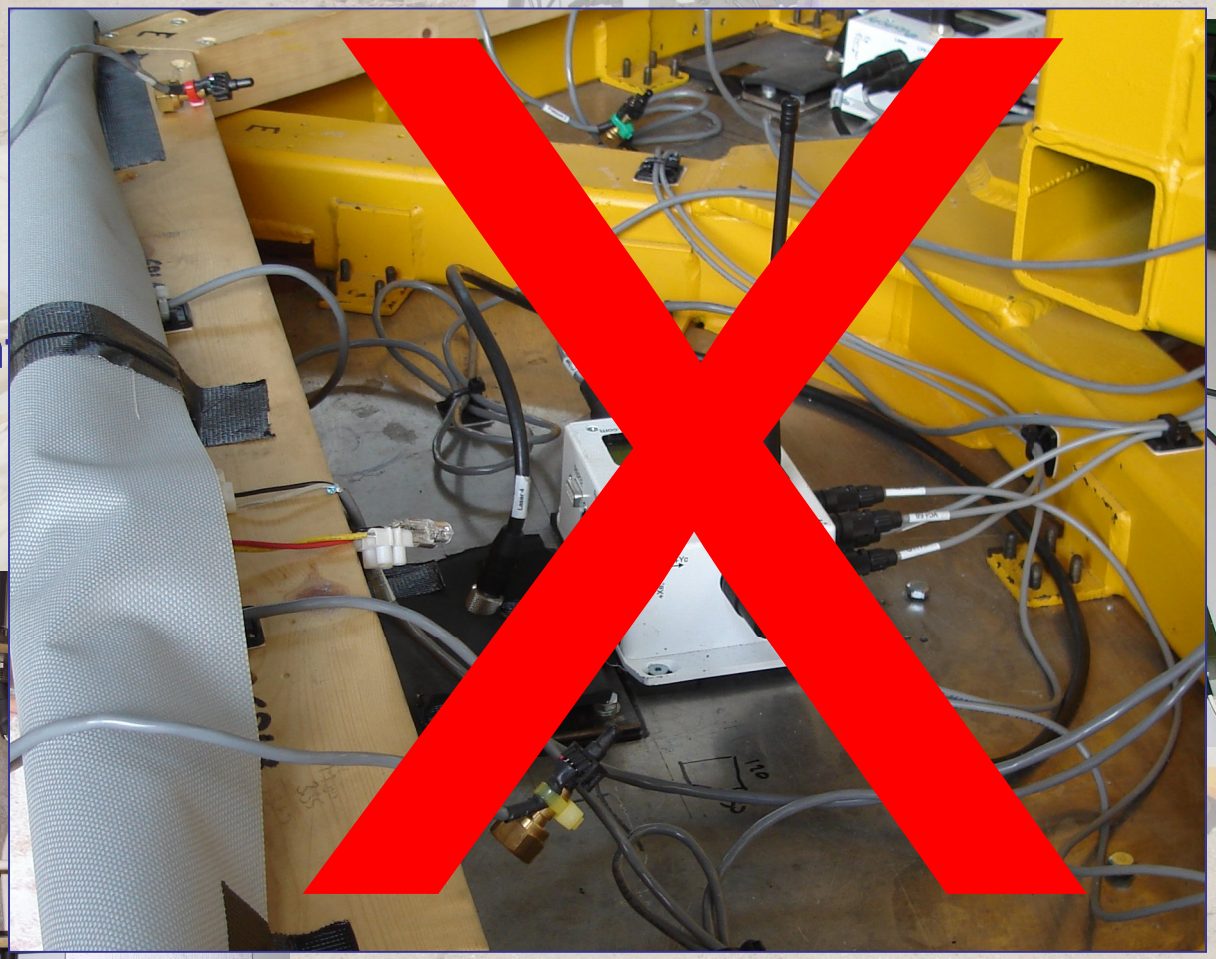
New ExoMars Requirements in 2008

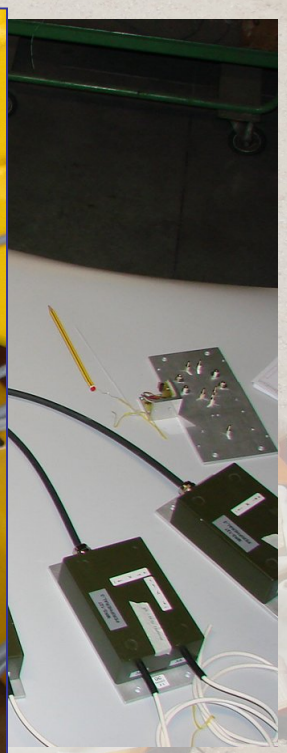
Lander mass:	600 kg
Vertical velocity at impact:	10 m/s
Horizontal velocity at impact:	3 m/s
Lander attitude at impact:	± 12 deg
Terrain slope:	± 18 deg
Rock clearance:	0.5 m
Max deceleration at impact:	40 g_E

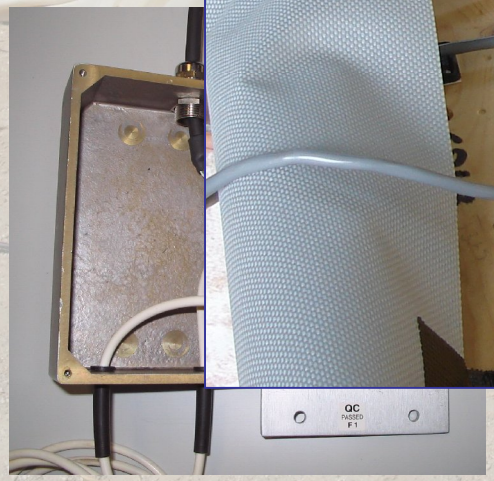
New Vent Control Logic

Vent Control System

Vent Con
Unit







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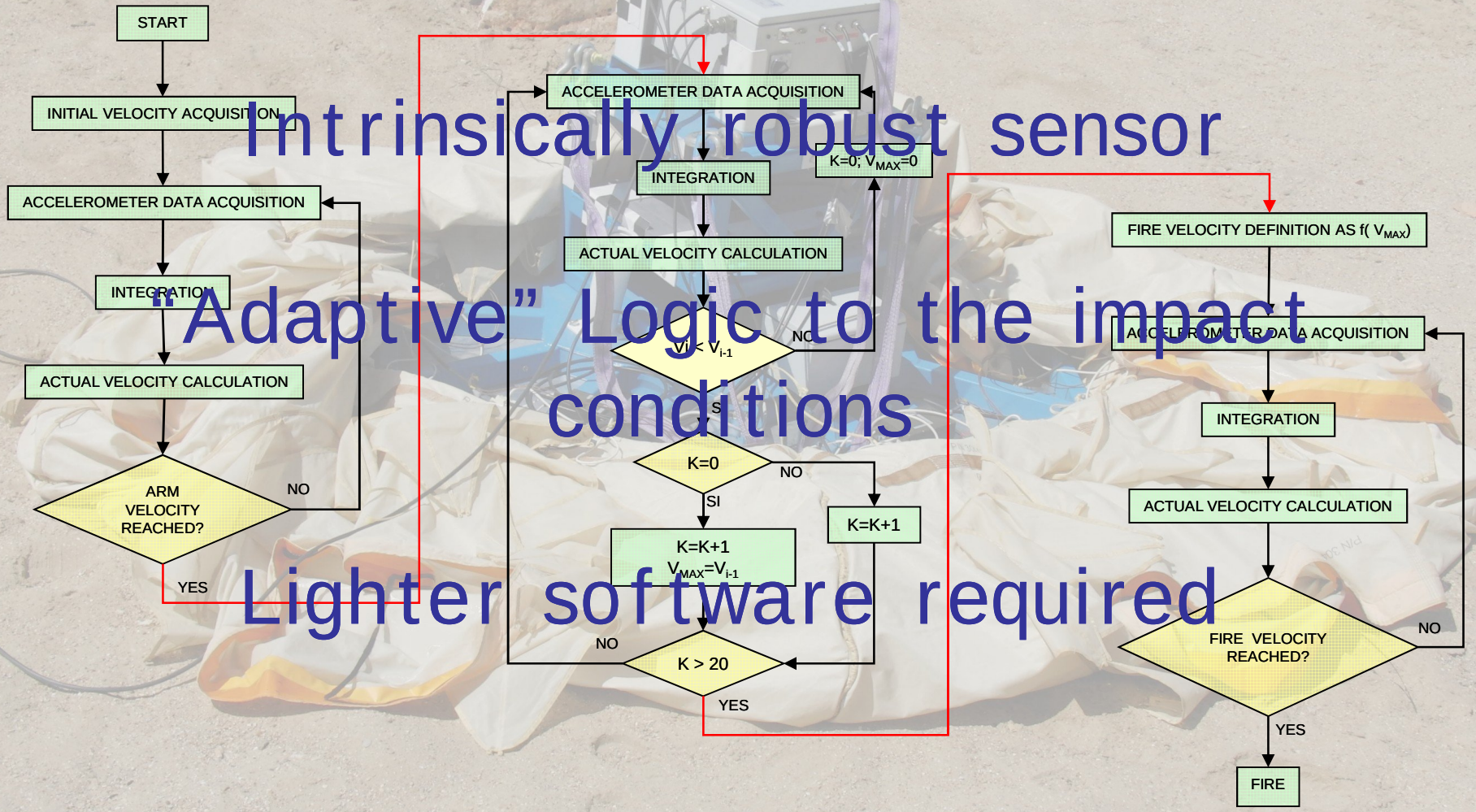
New Vent Control Logic

Intrinsically robust sensor

"Adaptive" Logic to the impact conditions

Lighter software required



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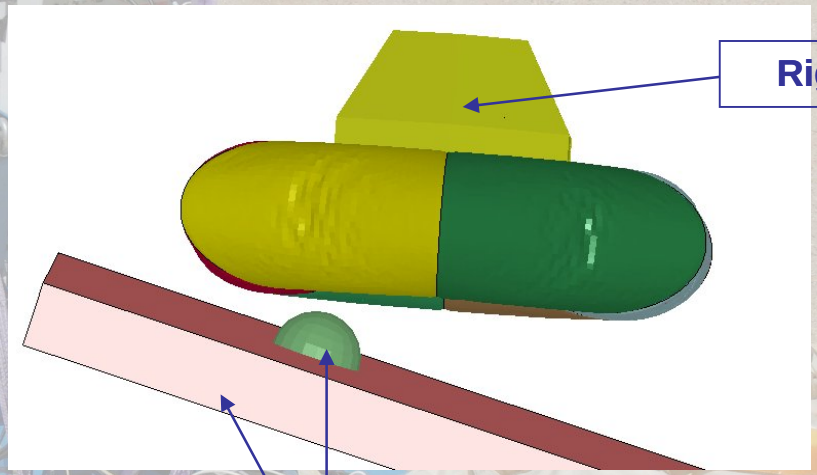
DYNA Model Correlation



Drop tests in Earth conditions → Dyna model correlation → Dyna simulations in Mars conditions

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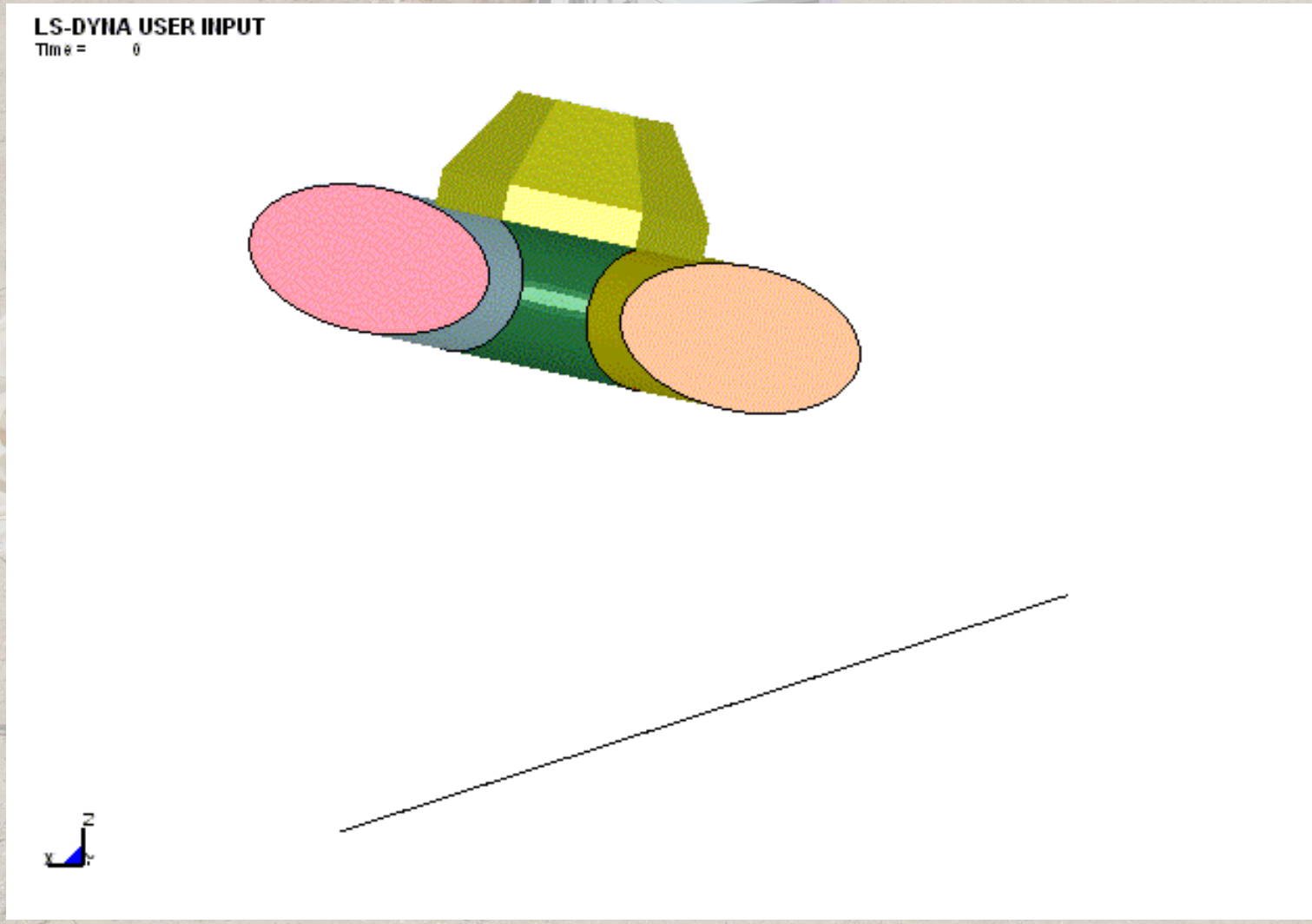
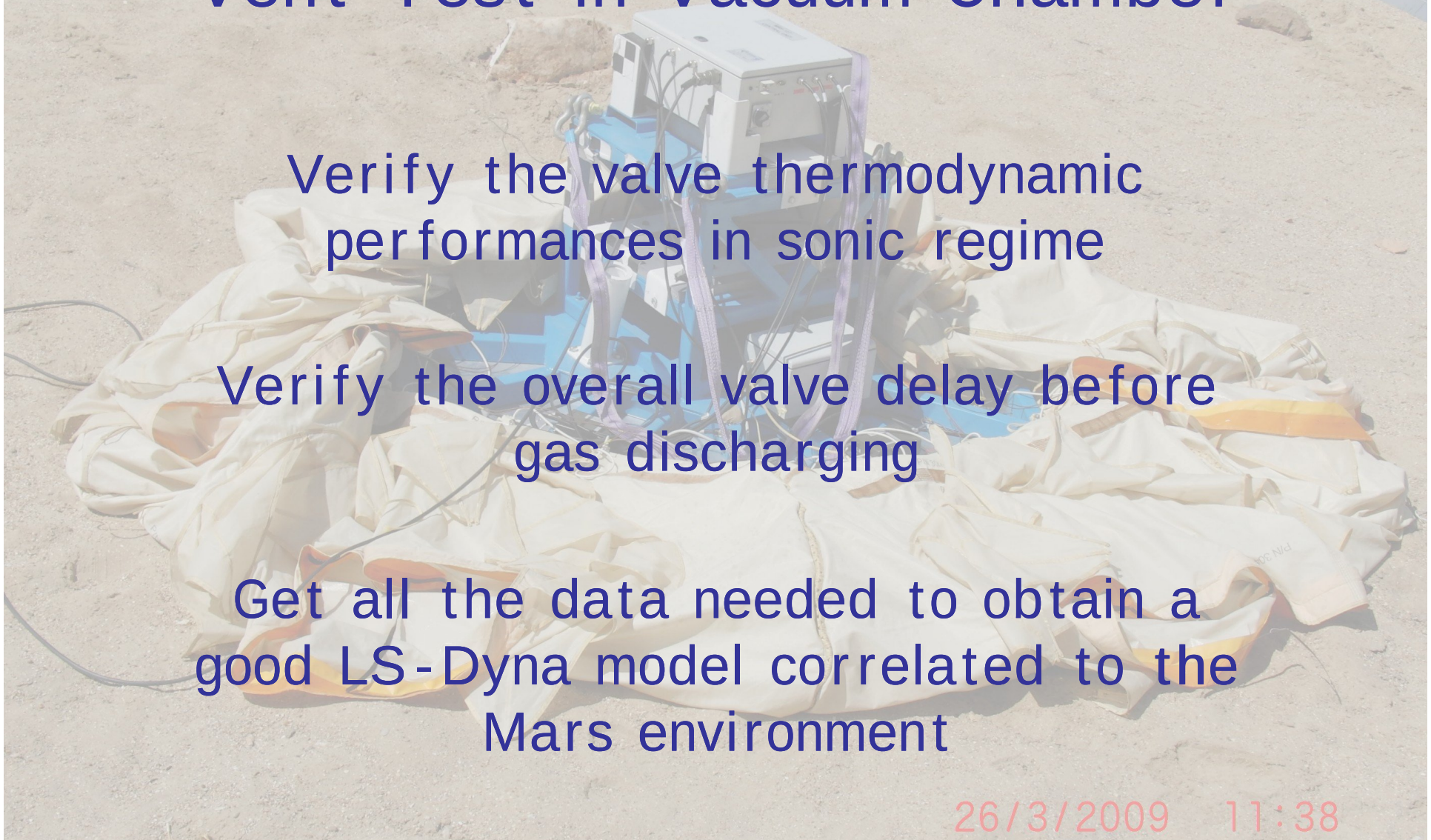
Drop Test Example (Earth)

DYNA Model Example (Mars)



Vent Test in Vacuum Chamber



Verify the valve thermodynamic performances in sonic regime

Verify the overall valve delay before gas discharging

Get all the data needed to obtain a good LS-Dyna model correlated to the Mars environment

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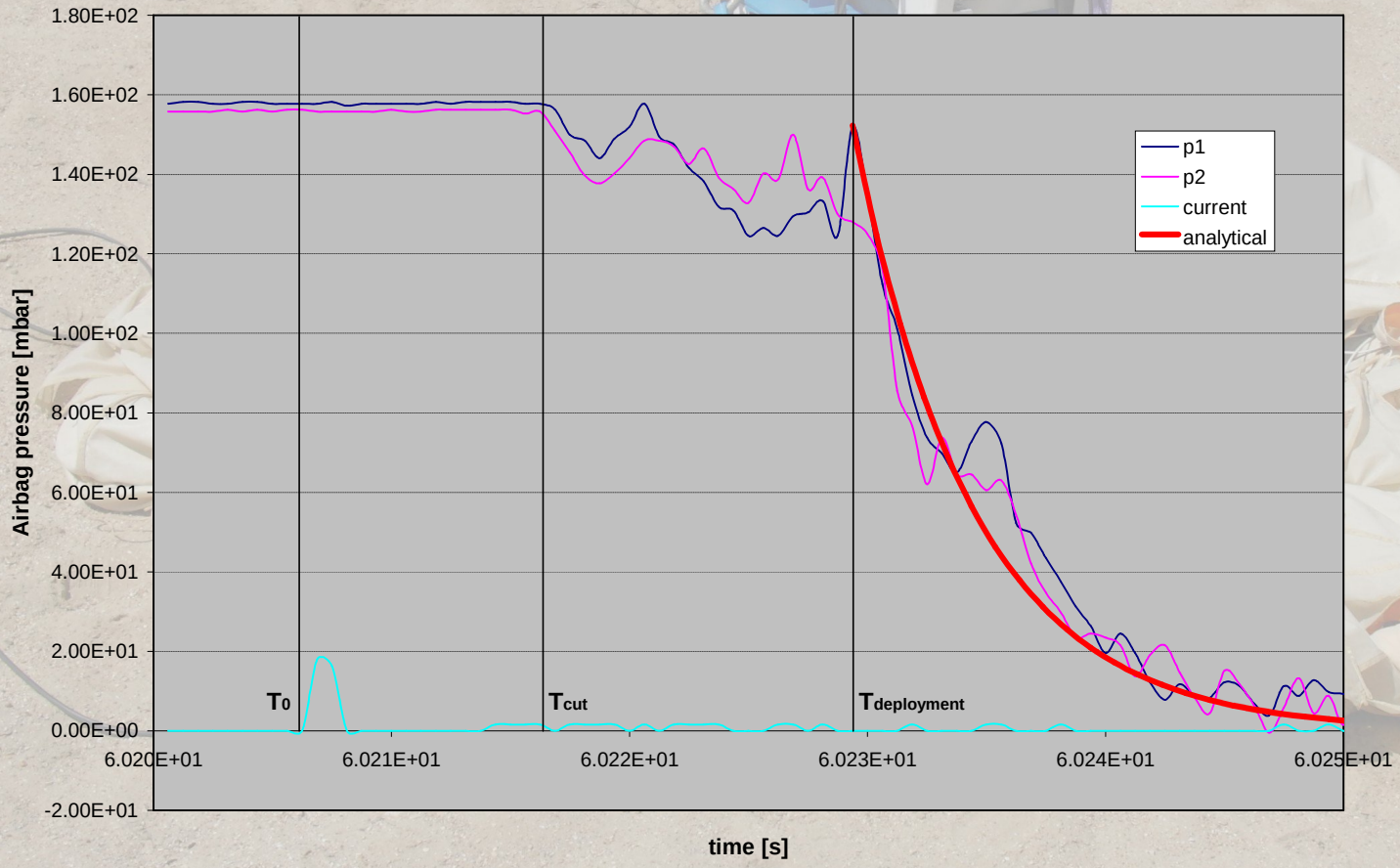
Vent Test in Vacuum Chamber



- Gas: Helium
- p=158 mbar
- p_{start}=152 mbar
- C_D=0.6

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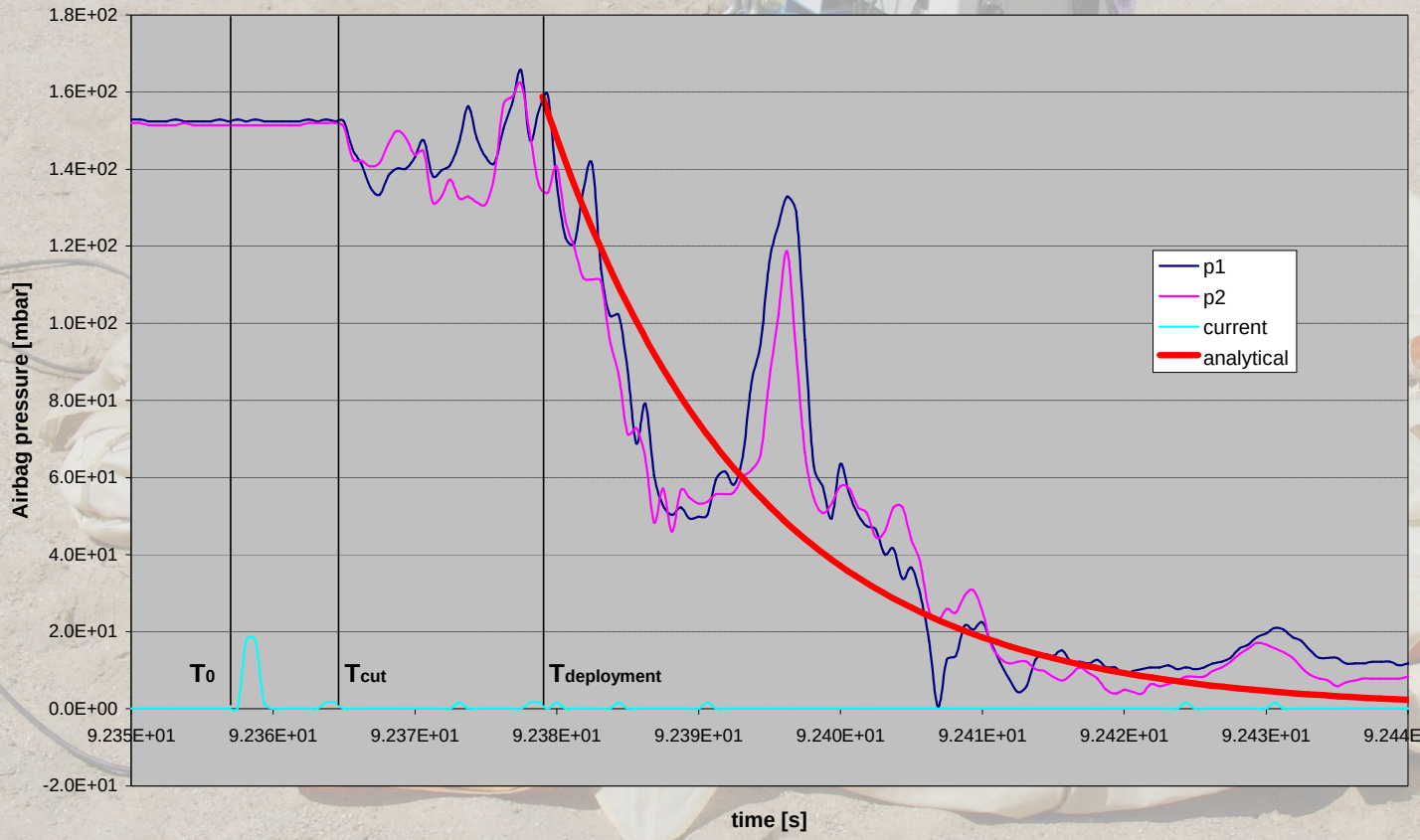
Vent Test in Vacuum Chamber



- Gas: Nitrogen
- p=153 mbar
- p_{start}=151 mbar
- C_D=0.6

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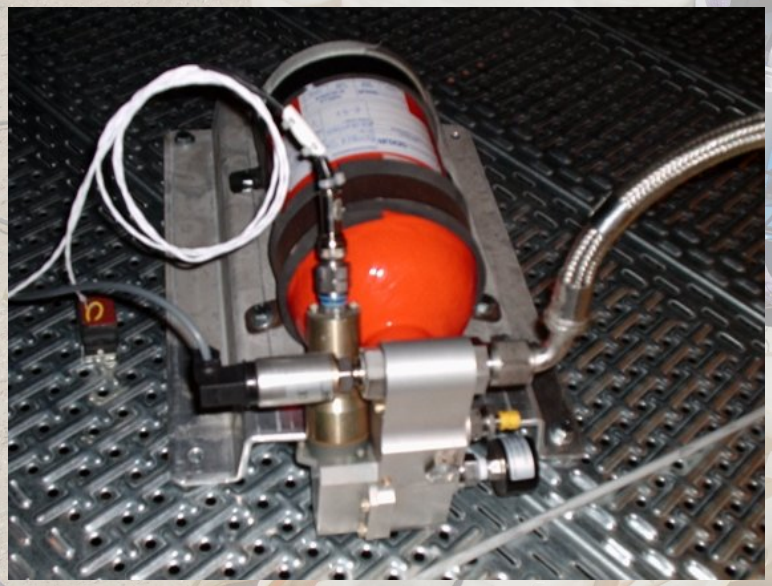
Inflation Test in Vacuum Chamber

Inflation System BB



Airbag in folded configuration

Inflation pressure of 112 barg in order to reach 160 mbar inside the segment

Helium gas used

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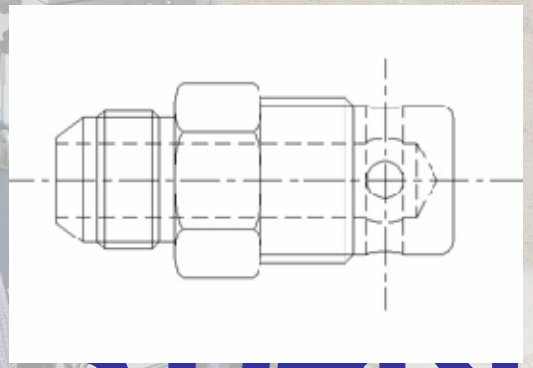
Inflation Test in Vacuum Chamber

Inflation system flange detachment from airbag fabric

Valve tube (in nylon film) burst due to the IS jet effect

FIRST TEST

Inflation Test in Vacuum Chamber



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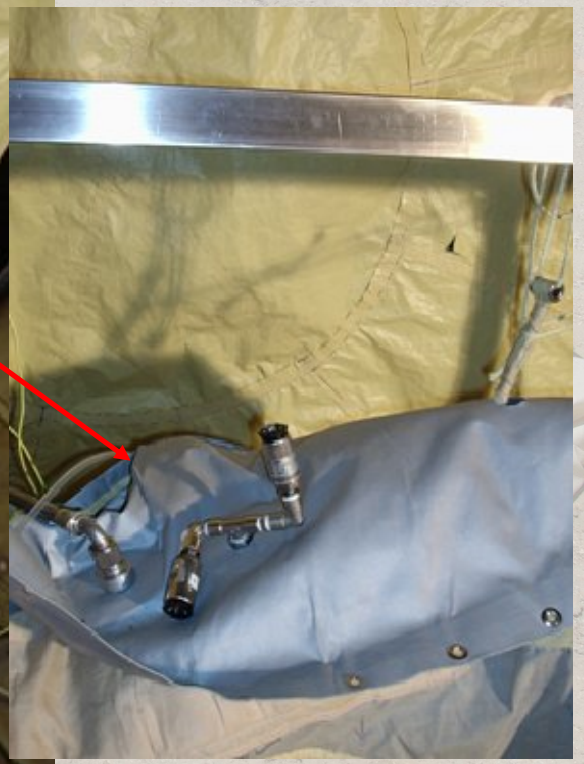
Inflation Test in Vacuum Chamber



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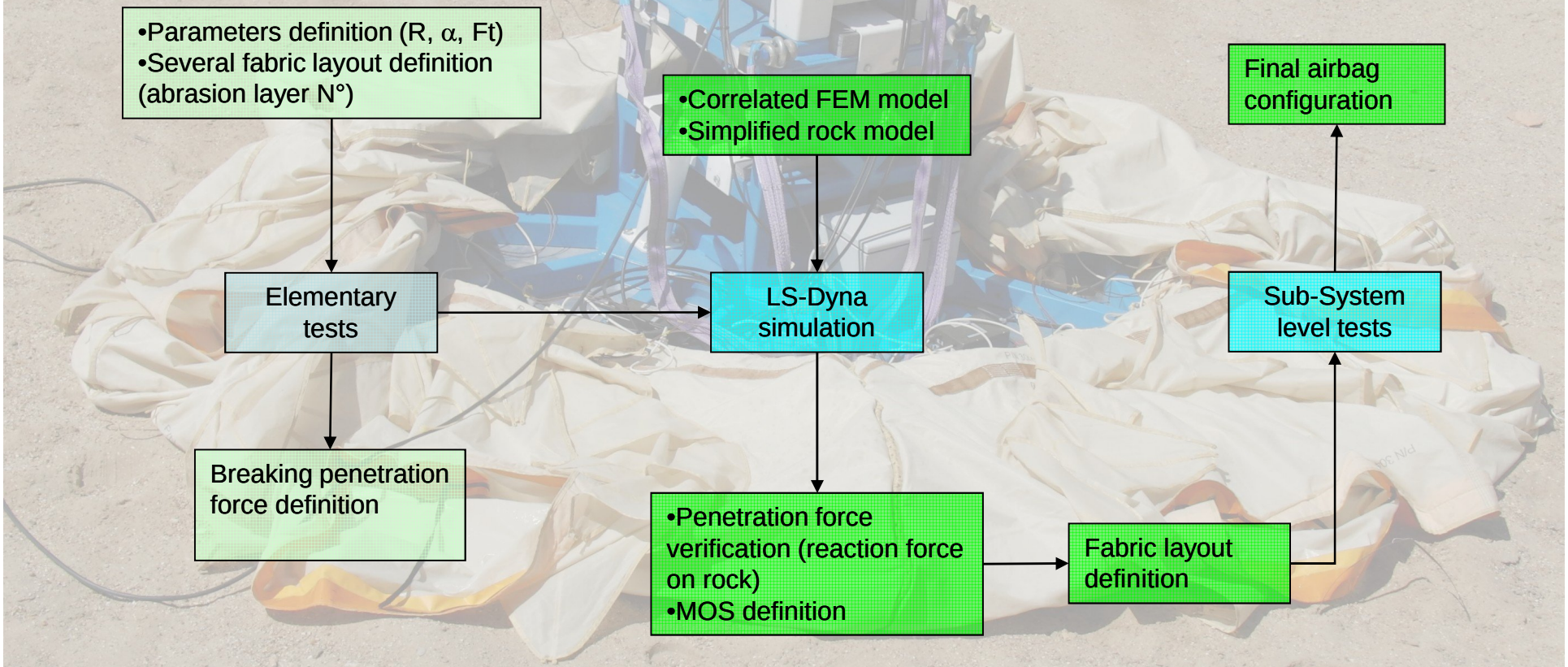
Inflation Test in Vacuum Chamber

Airbag Fabric Definition and Tests



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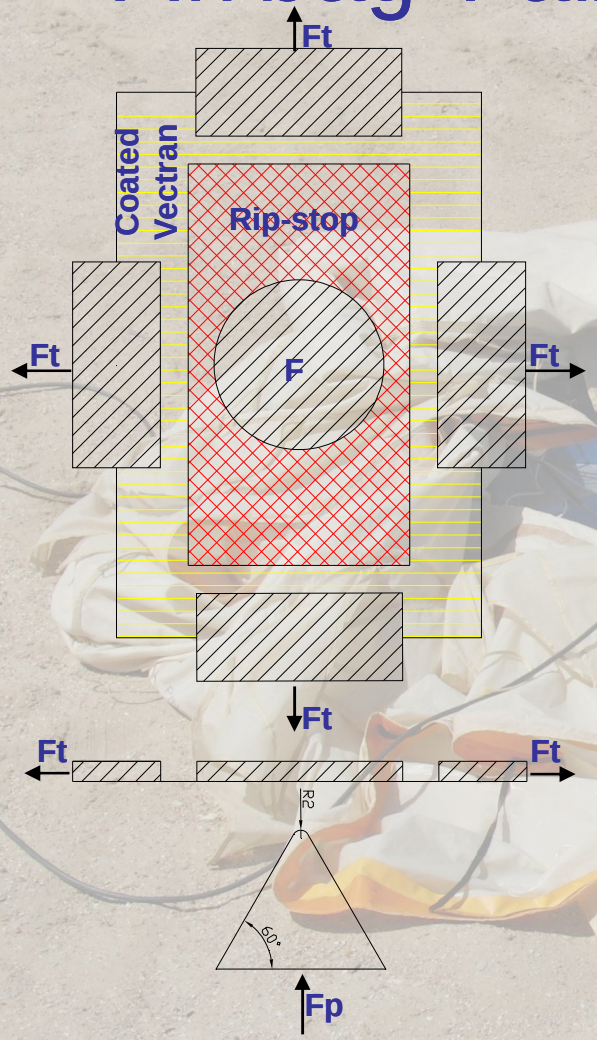
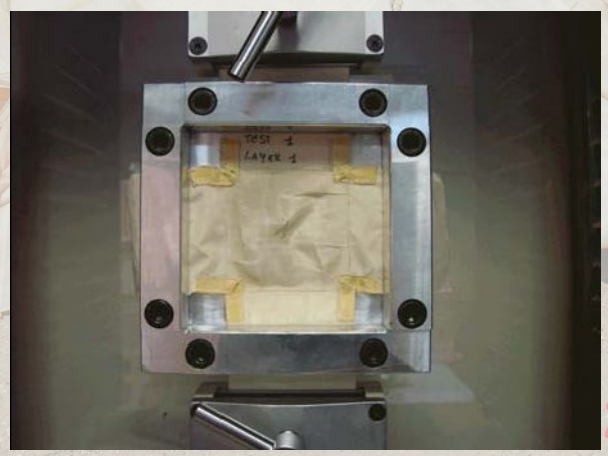
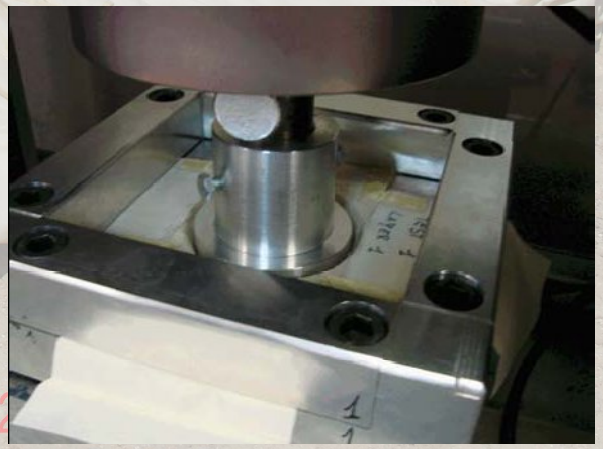
Airbag Fabric Definition and Tests



Elementary Tests

- **Configuration to be tested:**
  - Config1: 1 bladder + 1 abrasion layer
  - Config2: 1 bladder + 2 abrasion layer
  - Config3: 1 bladder + 3 abrasion layer
- **Parameters :**
  - Ft= 100N (2D traction force representative of ABS membrane stress)
  - R= 2mm (rock curvature radius)
  - α= 60° (rock aperture angle)
- **Fp_config1= 4153 N (average penetration force)**
- **Fp_config2= 4664 N (average penetration force)**
- **Fp_config3= 4818 N (average penetration force)**





Airbag Fabric Compatibility with DHMR

The sterilization activity has been performed in the ESTEC Dry Heat Sterilizer

- Number of cycles: three
- Duration of each: 30 hours
- Initially delay:
  - Cycle 1: 4 hours 56 minutes
  - Cycle 2: 3 hours 15 minutes
  - Cycle 3: 3 hours 18 minutes
- Temperature: 130 °C
  - Max: 130.24 °C
  - Min: 124.99 °C
- Packing density: 175 kg/m^3
- Temperature Sensors:
  - three thermocouples
  - chemical indicators
- Bio-indicators:
  - *Geobacillus stearothermophilus*
  - *Bacillus athrophaeus*

Airbag Fabric Compatibility with DHMR

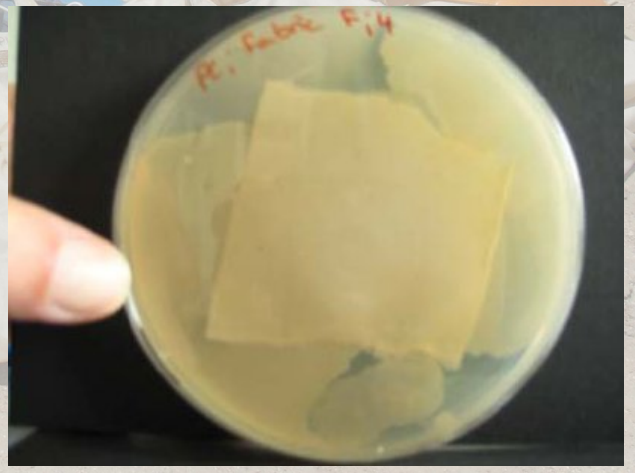
The test has been performed twice, after the first and second cycle.

After sterilization pieces (5x5 cm) of materials and bio-indicators have been put into Petri dishes and covered with TSA-Agar

The dishes have been incubated for 96h (checked after 24, 48, 72 hours).

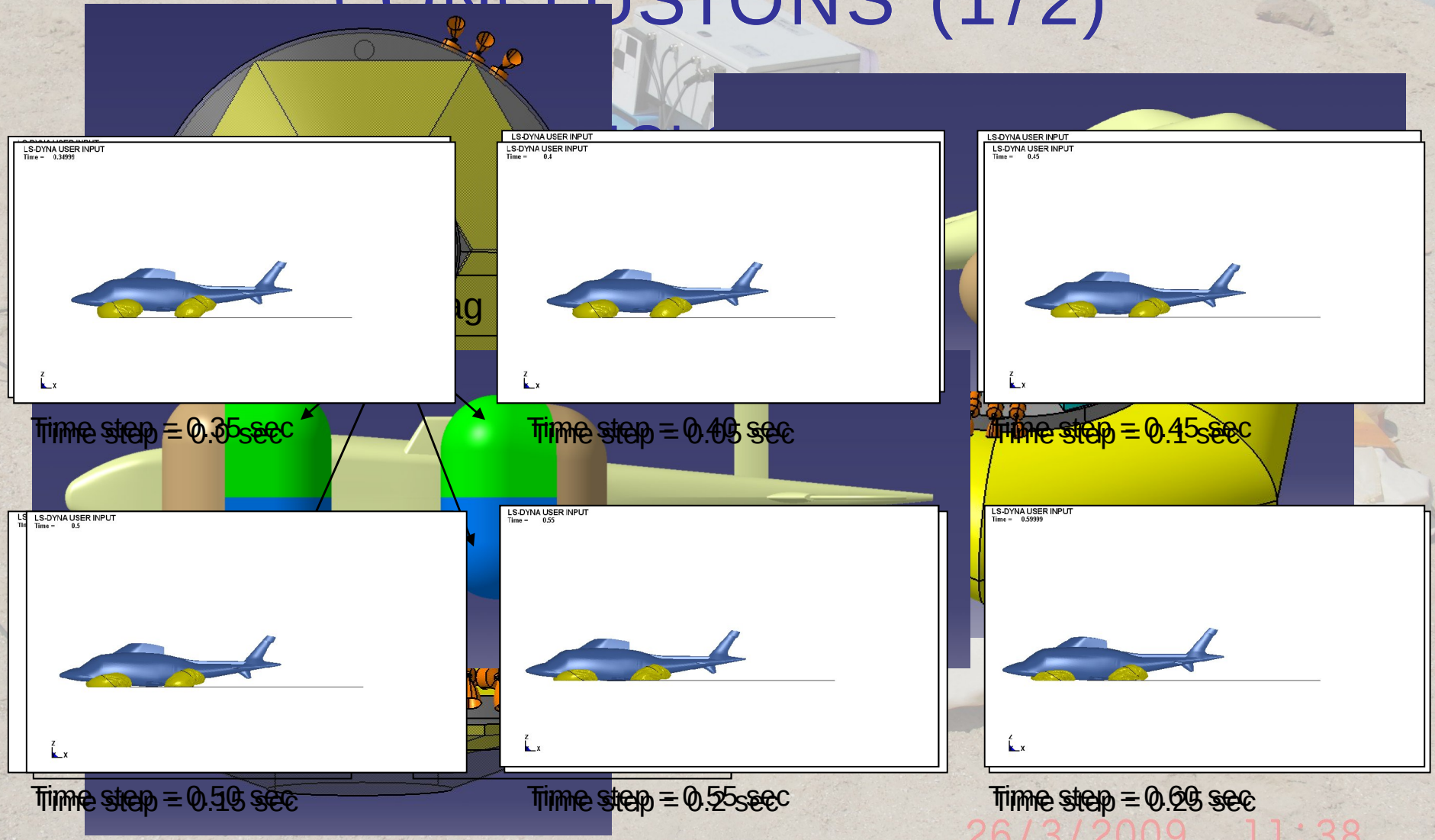
Cycle 1		
Bacteria	Location	count
GS	Bottom	1
GS	Bottom	1
GS	Bottom	0
BA	Bottom	0
BA	Bottom	0
BA	Bottom	0
GS	Middle	0
GS	Middle	0
GS	Middle	0
BA	Middle	0
BA	Middle	0
BA	Middle	0
GS	Top	0
GS	Top	0
GS	Top	0
BA	Top	0
BA	Top	0
BA	Top	0
GS + control		uncountable
BA + control		uncountable

Cycle 2		
Bacteria	Location	count
GS	Bottom	0
GS	Bottom	0
GS	Bottom	0
BA	Bottom	0
BA	Bottom	0
BA	Bottom	0
GS	Middle	1
GS	Middle	1
GS	Middle	2
BA	Middle	0
BA	Middle	0
BA	Middle	0
GS	Top	2
GS	Top	1
GS	Top	1
BA	Top	0
BA	Top	0
BA	Top	0
GS + control		uncountable
BA + control		uncountable



GS = Geobacillus stearothermophilus
BA = Bacillus athropheus

CONCLUSIONS (1/2)



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CONCLUSIONS (2/2)

Vented Airbag Technology (to be used for Mars Landing) needed development:

Inflation and Drop test verification in representative Mars ambient conditions

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THANKS FOR

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